PREPARING FOR THE IMPACTS OF CLIMATE CHANGE IN CALIFORNIA: OPPORTUNITIES AND CONSTRAINTS FOR ADAPTATION

WHITE PAPER

DRAFT

A Report From:
California Climate Change Center

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Arnold Schwarzenegger, *Governor*

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies

The California Climate Change Center (CCCC) is sponsored by the PIER program and coordinated by its Energy-Related Environmental Research area. The Center is managed by the California Energy Commission, Scripps Institution of Oceanography at the University of California at San Diego, and the University of California at Berkeley. The Scripps Institution of Oceanography conducts and administers research on climate change detection, analysis, and modeling; and the University of California at Berkeley conducts and administers research on economic analyses and policy issues. The Center also supports the Global Climate Change Grant Program, which offers competitive solicitations for climate research.

The California Climate Change Center Report Series details ongoing Center-sponsored research. As interim project results, these reports receive minimal editing, and the information contained in these reports may change; authors should be contacted for the most recent project results. By providing ready access to this timely research, the Center seeks to inform the public and expand dissemination of climate change information; thereby leveraging collaborative efforts and increasing the benefits of this research to California's citizens, environment, and economy.

For more information on the PIER Program, please visit the Energy Commission's website www.energy.ca.gov/pier/ or contact the Energy Commission at (916) 654-5164.

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Abstract

Governor Arnold Schwarzenegger's Executive Order S-3-05 of June 1, 2005 requested—among other things—that future climate change impact assessments for the State "report on mitigation and adaptation plans to combat these impacts." This report is an initial attempt to respond to that request. It examines California's opportunities and constraints for managing the impacts of climate change. This study reviews the extant literature on adaptation and provide examples from selected sectors in California to illuminate the constraints, and in some cases limits, to the ability to adapt to climate change. Based on these insights, the authors provide recommendations for how government, research, and civil society can help California most effectively prepare for climate change impacts.

Key Findings

Key Finding #1: California's response to climate change is not a simple choice between mitigating greenhouse gas emissions and adapting to the impacts of climate change. Adaptation and mitigation are necessary complementary strategies for managing climate change. The State must determine the portfolio of solutions that will best minimize potential risks and maximize potential benefits.

Key Finding #2: Today's climate variability and weather extremes already pose significant risks to California's citizens, economy, and environment. They reveal the State's vulnerability and existing challenges in dealing with the vagaries of climate. Continued climate changes, and the risk of abrupt or surprising shifts in climate, will likely further challenge the State's ability to cope with climate-related stresses in the future.

Key Finding #3: A deeper discussion is needed about the costs and challenges of adaptation in California and beyond.

Key Finding #4: To enhance Californians' preparedness for climate variability and change, decision-makers in the private and public sectors require greater *awareness* of the risks they face, increased capacity to *analyze* such information and use it in decision-making, and the ability to remove any institutional, financial, political, and other barriers in the way of turning good intentions into *actions*.

Key Finding #5: Many opportunities for enhancing California's adaptive capacity and resilience in the face of change exist. In fact, California's adaptive capacity—the *ability* to adapt—is significant. However, implementing that capacity into real adaptive actions on the ground is actually quite difficult and requires special attention and long-term commitment at all levels of government, across climate-sensitive industries, and throughout society.

Key Finding #6: The ability to cope and adapt is differentiated across population, economic sectors, and regions within the state. The State has an opportunity to ensure and enhance "environmental justice" while fostering California's adaptive capacity to climate change and other interactive stressors.

1.0 Motivation and Overview of this Report

Governor Arnold Schwarzenegger's Executive Order S-3-05 of June 1, 2005 called for specific emission reductions and a periodic update on the state of climate change science and the emerging understanding of potential impacts on climate-sensitive sectors such as the state's water supply, public health, agriculture, coastal areas, and forestry. In addition, the executive order requested that future impact assessments include a "report on mitigation and adaptation plans to combat these impacts." This report is a preliminary effort to respond to that request. It examines California's capacity to deal with the existing climate variability and assesses opportunities and constraints in preparing for potential future impacts of climate change.

The request for plans to cope with and adapt to the unfolding impacts of climate change opens up a critical opportunity to expand the much needed discussion on how society should manage the changes ahead. The growing focus on adaptation is thus welcome and timely.

Climate policy has often been presented as a choice between mitigation and adaptation (Tol 2005, Smit et al. 1999, Tol et al. 1998, NAS 1992), where *mitigation* refers to reducing the accumulation of greenhouse gases in the atmosphere and *adaptation* refers to adjusting to the impacts of a warming world through reducing vulnerability and enhancing ecosystems', sectors' and society's resilience in the face of change (see Textbox 1).

Textbox 1: Definition of Key Concepts and Terms

Mitigation – The reduction of heat-trapping greenhouse gas emissions into the atmosphere.

Adaptation – The range of adjustments of the environment or those taken by individuals, organizations, communities, or other entities to deal with the potential or experienced impacts of climate change.

Vulnerability – The extent to which a natural or social system is susceptible to sustaining damage from weather extremes, climate variability and change (and other interactive stressors).

Adaptive Capacity – The ability of a system to anticipate and adapt to the potential or experienced impacts of climate change. Sometimes equated with and other times distinguished from **Coping Capacity** – The ability of a system to deal with the impacts of present-day weather extremes or climate variability.

Resilience – The ability of a system to absorb and rebound from the impacts from weather extremes, climate variability or change and to continue functioning.

This perception of mitigation and adaptation as alternative or "substitute" responses to global warming evolved in part as a result of the belief that climate change was primarily a problem of the future with impacts resulting from slow, gradual and highly uncertain processes (Figure 1). This dichotomous paradigm is being currently replaced in the policy and research communities by a perspective that views them instead as complementary. Research efforts focus on delineating how mitigation and adaptation efforts can be employed synergistically, or at least implemented in a way that they do not counteract each other or produce negative ancillary effects and costly trade-offs (Klein et al. 2005, Tol 2005, Wilbanks 2005, Wilbanks et al. 2003, Kane and Shogren 2000).

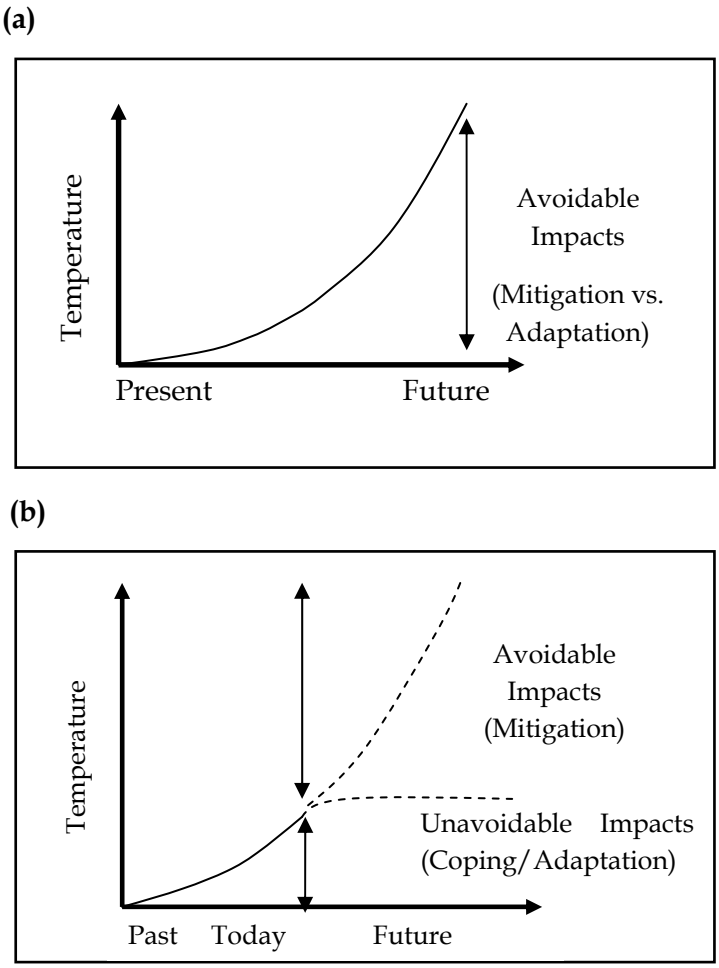

Figure 1: Alternative Framings of Societal Response Options to Climate Change

Figure 1 (a) depicts mitigation and adaptation as an either/or choice, where the reduction of impacts can be achieved either through mitigation or through adaptation. This framing is now recognized as misleading because mitigation of current emissions will have no impact on near-term impacts that result from the time-delayed changes in climate resulting from past emissions. Figure 1 (b) represents the more accurate understanding that coping and adaptation is needed to deal with the unavoidable impacts in the near-term while mitigation is needed to prevent further, and more severe impacts in the future.

California's response to climate change is not a simple choice between mitigating greenhouse gas emissions and adapting to the impacts of climate change. Adaptation—while it is not the ultimate solution—is a necessity because climate change is demonstrably underway, the first impacts are already being observed, and further impacts over the next 30 years are unavoidable due to the emissions already released into the atmosphere and the time lag in the climate system. At the same time, the state's long-term ability to cope with climate impacts depends on the pace and magnitude of global climate change. These facts make adaptation and mitigation necessary complementary strategies to deal with climate change, and the State must determine the portfolio of solutions that can best minimize potential risks and maximize potential benefits.

Key Finding #1: California's response to climate change is not a simple choice between mitigating greenhouse gas emissions and adapting to the impacts of climate change. Adaptation and mitigation are necessary complementary strategies for managing climate change. The State must determine the portfolio of solutions that will best minimize its potential risks and maximize its potential benefits.

This report does not focus on mitigation but begins to examine the many opportunities for enhancing California's adaptive capacity and resilience in the face of change. It highlights the ways in which the ability to cope and adapt is differentiated across populations, economic sectors, and regions within the state. The State has the opportunity, and some would argue responsibility, to focus its attention and resources in ways that ensure and enhance "environmental justice" while fostering California's adaptive capacity to climate change and other interactive stressors.

Below is a summary of the insights from the extant literature on adaptation and provide examples from selected sectors in California to illuminate the opportunities and constraints, and in some cases limits, to the ability to adapt to climate change. Examples are drawn primarily from the water, coastal, and fire management sectors based on the authors' expertise. Future work should examine these and other sectors more thoroughly.

Section 2 argues that it is necessary to pay critical attention to preparedness and the ability to adapt to climate change now. Opportunities for and constraints on adaptation, including the differential ability to cope with climate change across the State, are discussed in Section 3, and conclusions and recommendations are offered in Section 4.

2.0 A Critical Time to Look at Adaptation

2.1. Present-Day Vulnerabilities and Unavoidable Impacts in the Near Term

In times of disaster the vulnerabilities of society are revealed. Over recent years, the Western United States has experienced extended droughts, putting significant strain on the region's and California's water management systems and imposing severe restrictions on agriculture. Similarly, the El Niños of 1987, 1992 and 1997 are still "marker events" in the memory of many Californians for the havoc they created along the state's coastline, straining not only emergency response capabilities and causing significant economic damages to private and public property, but also exposing the risky implications of past management, planning, and development decisions.

While none of these events can be attributed to human-induced global warming, their devastating impacts raise serious questions about society's vulnerability to, and its ability, willingness, and preparedness to cope with, climate variability and change.[1]

As local, regional and international communities work towards slowing the rate of warming through the reduction of greenhouse gas emissions global climate continues to change in response to the emissions already released to the atmosphere from human activities in the past. It is now evident that even if actions could be taken immediately to dramatically curtail the global emissions of greenhouse gases, the inertia of the Earth's climate system is such that 0.5°C (0.9°F) or more of additional warming would still occur (Hansen et al. 2005, Meehl et al. 2005, Wigley 2005). This suggests that a global, concerted effort is needed to curtail emissions and thus slow down human-induced global warming. At the same time, society has to increasingly focus on enhancing its capacity to cope with the already occurring and unavoidable impacts that we will experience over the next few decades, no matter what emission-reducing steps will be taken.

Empirical observation and scientific analyses of historical trends in climatic and ecological indicators in California are consistent with global trends and with the early impacts expected from global warming: temperatures are increasing, precipitation patterns are changing, and species are responding already in the state (Table 1). These early impacts and trends in California and elsewhere in the U.S. and the world (for additional examples see CEC 2005; Parmesan and Galbraith 2004; Smith and Galbraith 2003) serve to underline the need for the State to begin examining its ability to adapt to climate variability and change.

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[1] The term "climate variability and change" is used in this report as it is commonly used in the adaptation literature (even if that usage is not precise from a physical science perspective). It includes phenomena at various temporal and spatial scales such as individual weather extremes, seasonal, inter-annual, and multi-decadal climate variability, and long-term climate change.

Table 1: Selected Trends in Indicators of Climate Change and Observed Impacts in California

Indicator	Region	Trend	Number of Years Observed	Reference
Winter temperature	Statewide	0.6° C (1.1°F) per decade between 1950-1997	47	Mote et al. 2005
Snowpack	High-elevation Sierra Nevada	20%-80% increase [1997 relative to 1950]	47	Mote et al. 2005
Snowpack	Low-elevation Sierra Nevada	20%-80% decrease [1997 relative to 1950]	47	Mote et al. 2005
Glaciated area	Lyell Glacier, Sierra Nevada	30%-70% decrease [since 1883]	120	Basagic and Fountain 2005
Spring stream flow pulse	Statewide	10-30 days earlier [1948-2002]	54	Stewart et al. 2005
Lilac bloom date	Western U.S.	7.5 days earlier from [1957 to1994]]	38	Cayan et al. 2001
Honeysuckle bloom date	Western U.S.	10 days earlier from [1957 to1994]	27	Cayan et al. 2001
Species composition in rocky intertidal communities	Southern Monterey Bay	0.79°C (~1°F) warming of nearshore ocean temps since [1931-1933], southern species increasing, native northern species declining	60	Sagarin et al. 1999
Edith's Checkerspot Butterfly	Statewide	north- and upward shifts in species range [observation period: ~1962 to 1992-1996]	30+	Parmesan 1996
Sachem Skipper Butterfly	Statewide	Northward range expansion [observation period: 1965-1999]	35	Crozier 2003
Total annual number of fish species	Southern California	Decline of cold-water species, increase of warm-water species [observation period: 1960–1995]	25	Holbrook et al. 1997

Studies that project future climate and its impacts on California and the western United States suggest that even modest climate warming will exacerbate these already-observed changes. For example, the most recent projections for California indicate continued warming in the state over the 21st century but the rate of warming depends on the

amount of greenhouse gas emissions (Hayhoe et al. 2004). Of particular concern are potential impacts on California's water supply, human health, coastal areas, and natural (unmanaged) ecosystems, as well as on agriculture, forestry (including related fire management), and the energy sector, which are highly sensitive to changes in temperature and water availability.[2]

In addition to the expected changes in average temperature and precipitation, changes in climate variability are also of significant concern. In fact, changes in climatic extremes have already been observed (e.g., more extreme rainfall and heat events, see e.g., Karl and Knight 1998), and—while scientifically more uncertain than changes in average temperature—numerous studies expect variability to increase further in the future (IPCC 2001b, Easterling et al. 2000). Changes in regionally important inter-annual climate variability related to the El Niño--Southern Oscillation (ENSO) or the Pacific Decadal Oscillation (PDO), for example, which can produce major strains in climate-sensitive sectors, remain subject of debate in the scientific community at this time, but would be critically important to California.

In summary, because human-induced climate change is underway, early impacts are already evident, further impacts over the next few decades are unavoidable, and projections of future change suggest growing challenges from global warming to California, the state must confront the need to adapt while recognizing and addressing the constraints or limits on adaptation over the long term.

2.2. The Risk of Major Climate Shifts and Abrupt Changes in the Future

The estimates of societal benefits of expending scarce resources today to mitigate uncertain future climate change depend considerably on the assumptions about the sensitivity of the climate system to greenhouse gas emissions, i.e., on the estimated warming resulting from a doubling (compared to pre-industrial levels) of CO_2 concentrations in the atmosphere. While the consensus estimate of mean climate sensitivity remains on the order of 2°C-3°C (Kerr 2004), it is now recognized that the distribution of this uncertain quantity may have greater weight in its upper tail than previously assumed (Andronova and Schlesinger 2001, Allen and Ingram 2002, Gregory et al. 2002, Knutti et al. 2002, Webster et al. 2003, Stainforth et al. 2005). This heavier emphasis on the upper end of the probability distribution implies an increased likelihood that the upper bound of the change in global mean temperature from a doubling of atmospheric CO_2 concentration may be considerably higher than previously estimated. This also entails an upward revision of the upper bound on estimated potential damages. In other words, society's gamble to *not* invest in mitigation, and/or to *not* invest in avoiding potentially more severe climate change, is now believed to be a worse bet than previously thought.

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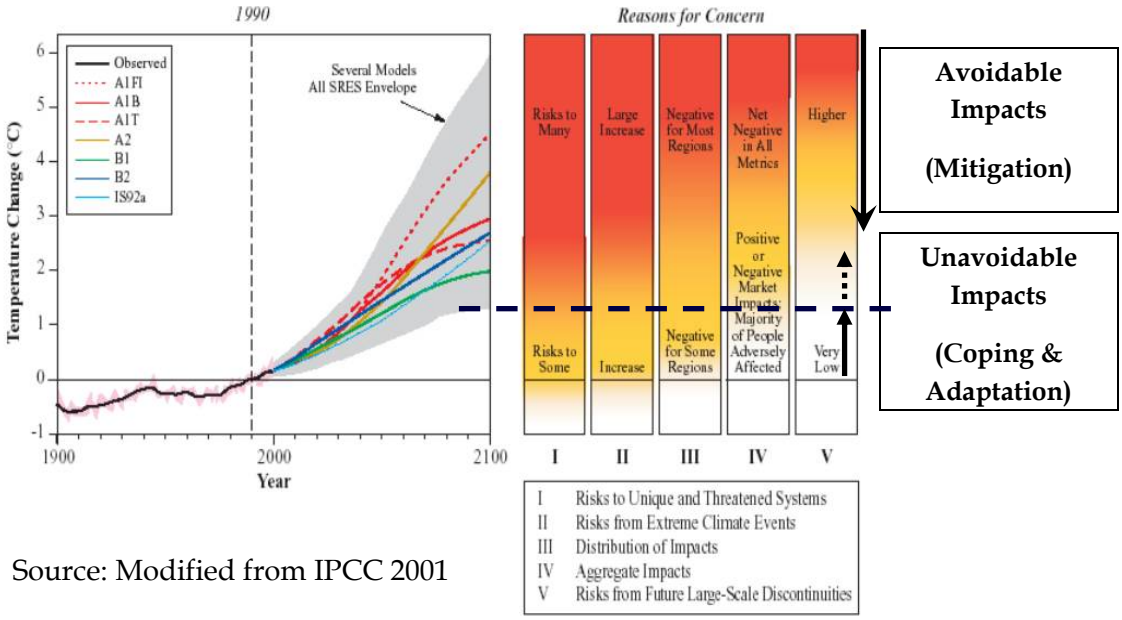
[2] For updated impact assessments on these sectors and extensive reviews of the relevant literature, see the reports prepared for Energy Commission/CalEPA by other research teams for the Governor's *Scenarios Report*.

Furthermore, although there remains much uncertainty around the specific impacts of climate change, it is important to remember that embedded in this uncertainty is the possibility of catastrophic change (Schneider and Azar 2001; Mastrandrea and Schneider 2004, Schneider 2004). In fact, the complex dynamics of the climate system imply that significant changes should not only be expected in the long-term as a result of gradual changes: Paleo-climatic evidence demonstrates that very rapid shifts in the climate regime have occurred in the past, and it is now recognized that such "nonlinearities" might recur as a result of anthropogenic emissions (NAS 2002). The potential collapse of the North Atlantic Thermohaline Circulation is perhaps the best-known example, but the possibility of abrupt climate change is not limited to this phenomenon.

Figure 2 highlights the urgency of both emissions abatement and adaptation by illustrating the growing severity and potential non-linearity of impacts with rising temperatures.

Key Finding #2: Today's climate variability and weather extremes already pose significant risks to California's citizens, economy, and environment. They reveal the State's vulnerability and existing challenges in dealing with the vagaries of climate. Continued climate changes, and the risk of abrupt or surprising shifts in climate, will likely further challenge the State's ability to cope with climate-related stresses in the future..



Source: Modified from IPCC 2001

Due to the long residence time of heat-trapping greenhouse gases in the atmosphere and the long time lags in the climate (and related complex Earth) systems some impacts from past emissions can not be avoided. Adaptation to these impacts is an unavoidable necessity. For the same reason (time lags), and unpredictable but imaginable surprise responses of the climate system to large and rapid forcing, however, mitigation must begin now to avoid "dangerous interference in the climate system," i.e., major and widespread aggregate ecological and socio-economic impacts and the possibility of large-scale discontinuities.

Figure 2: Managing Impacts of Climate Change through Mitigation and Adaptation

2.3. The Missing Debate about Adaptation "in the Real World"

Although adaptation has increasingly gained attention in the international global environmental change research and policy communities (see, e.g., summaries of the research in IPCC 2001b; or the adaptation-related goals in the UN Framework Convention on Climate Change, United Nations 1992), U.S. public discourse of the need and options for, and possible constraints on, adapting to climate change remains limited. The limited discussion on adaptation in the American public is in large part due to the fact that climate policy is dominated by two groups. On the one hand, there are those that continue to deny and actively question the reality of climate change and further believe that even if climate change were to become a problem in the future, Americans would be able to adapt and that therefore there is no need to take action now either to prepare or to mitigate (see, e.g., the discussion in Kates 1997). The view that the United States can cope with whatever climate change may bring has remained largely unquestioned to date, maybe in part because of a confusion between *adaptive capacity* in a general sense (e.g., as indicated by a high GDP or average per capita income) and the *implementation of that capacity* in real action in specific places. More recently, some have

tried to substantiate the idea that human systems have almost unlimited capacity to adapt to change[3] but not the financial resources to invest in major mitigation efforts (e.g., Goklany 2000, 2005). These typically very coarse-scale economic assessments compare the relative benefits of expending resources on economy-wide mitigation versus adaptation in a small number of selected sectors arguing that spending money on economic development and adaptation should be the exclusive response to climate change, especially in the near-term. They do not examine the full range of costs economy-wide, nor do they explore the implementation challenges of adaptation "on the ground." Moreover, they only focus on human systems, not the natural environment on which humans depend. Ecological impact assessments have reiterated repeatedly, however, that natural and unmanaged species and ecosystems are unlikely to be able to adapt as global warming accelerates (e.g., IPCC 2001b; Schneider and Root 2002).

Another important reason for the limited public debate about adaptation has been the influence of those, including in the environmental advocacy community, who would rather avoid talking about adaptation because of a concern that it would distract from the need for mitigation, or because doing so would be perceived as defeatist (e.g., Burton 1994). In addition, because of the close linkage between poverty and economic marginality on the one hand and the limited ability to cope with weather extremes, climate variability and change on the other, the scientific community has focused most of its attention on questions of adaptation on the poorest and most vulnerable in developing countries. This, too, is beginning to change (e.g., CBCF 2004). The combination of all these reasons may help explain why the media have been largely silent on the topic of adaptation as well. Thus, adaptation has not yet emerged in California and in the United States more generally as a legitimate and needed subject for public and policy debate, leaving Americans ill-prepared for the complex challenges already existing today and waiting ahead.

Key Finding #3: A deeper discussion is needed about the costs and challenges of adaptation in California and beyond

[3] This belief is being challenged increasingly in the scientific literature through theoretical and empirical studies (e.g., Moser 2005, Tompkins and Adger 2005).

3.0 Opportunities and Constraints in Adapting to Climate Variability and Change

If the need for adaptation is taken seriously then at the local, state, national and international levels, questions arise as to what can be done and through which institutional mechanisms to prepare for the unavoidable and uncertain future impacts, how that can be done most cost-effectively, and how it should be done to minimize the negative social and environmental side effects. Answers need to be found in the context of not just climate variability and change, but multiple stressors (Section 3.1)

Fortunately, as we will illustrate with examples below, many opportunities exist to decrease society's vulnerability to current weather extremes and climate variability. Such measures will go a considerable way toward increasing society's resilience in the face of change. A growing body of research shows that proactive measures to address climate change impacts prove more cost-effective and efficient then reactive (i.e., post-impact or post-disaster) measures (e.g., Schneider et al. 2000, Easterling et al. 2004). With conscious planning, such measures can be realized in the course of numerous short-term operational and longer-term strategic planning and management decisions (Paavola and Adger, 2002). For example, so-called no-regrets measures and policies include actions that are already justified by current climatic conditions but may have even greater value when changes in climate are considered, or actions that can be justified as protection against future climate change impacts but which already produce environmental and social benefits today. For example, improved water conservation measures can alleviate water shortages in dry years under current climate; however, water conservation would prove even more valuable as climate change increases pressures on California's water system by diminishing supply and increasing demand (for additional examples see Wilkinson 2002).

Alternatively, "low-regrets" strategies are those that—in the course of regular infrastructure upgrading and maintenance such as replacement of sewage pipes or long-term development planning and siting—can incorporate "safety buffers," for example, to account for potentially more extreme runoff or higher sea levels without incurring huge additional costs at the time of the upgrade. In cases where present-day weather extremes and climate variability cause damages, additional opportunities exist during the recovery period to rebuild in ways that are informed by the possibility of future climate change. This paper explores a range of such no- or low-regrets options in Sections 3.2 and 3.3).

It would be wrong to assume, however, that just because many opportunities for preparedness and adaptation exist, that they will all be taken or smoothly implemented. In fact, if one views adaptation to climate (past and current climate variability and change) as an ongoing part of the human-environment relationship (Burton et al. 1993; Lamb 1982), and acknowledges the multi-billion dollar impacts that weather- and climate events have on society worldwide today, then this point becomes painfully evident. Adaptation—whether planned or unplanned, or undertaken in the private or public sector—is imperfect (i.e., measures are not always perfectly timed, efficiently

implemented, or wholly adopted because of a variety of constraints and barriers) (Section 3.4). This is easily illustrated by the fact that current society is not perfectly adapted to weather and climate—costly disasters and losses occur every year. Moreover, what may appear as the most reasonable pathway to adaptation may sometimes be completely avoided or can generate social injustices and negative ecological ancillary effects (Section 3.5). Thus significant efforts need to be made to improve forward thinking and to prevent mal-adaptations (e.g., Schneider et al. 2000, West and Dowlatabadi 1998). Clearly, as some of our case examples below will illustrate, effective adaptation takes time and committed staff and resources.

Finally, there are limits to adaptation, especially in addressing the threats of abrupt climate changes or in dealing with those to natural, unmanaged species and ecosystems, which may or may not be able to keep up with the increasingly rapid and severe climate change expected in future decades. These constraints and limitations illustrate why reliance on adaptation alone is misplaced and why mitigation must remain an indispensable part of the response portfolio required to reduce the threats from unanticipated or rapid climatic changes.

3.1. Climate in the Context of Multiple Other Stressors

The effects of climate variability and change are not experienced in isolation. For example, while a drought may cause severe challenges to agricultural production, population pressures, price fluctuations, market competition, and technological innovation interact to determine how severely a farmer may experience the drought and what the options are responding to it. Other natural and social systems may be subject to stresses such as economic down-turns, degradation in air and water quality, urbanization, or disease. For example, population growth and increasing development in the wildland–urban interface are believed to be increasing the risk of wildfires in many regions (Cova 2005, Fried et al 2004). Climate change is expected to exacerbate these problems by increasing the severity and frequency of fire hazards (Fried et al. 2005, Lenihan et al. 2003, Brown et al. 2005). As a result, because climate pressures cannot be substantially minimized over the short term, there is increased incentive to reduce non-climatic pressures as way to decrease vulnerability climatic extremes. In the case of wildfire management this might include creating zoning laws that limit development in high risk regions (Cova 2005).

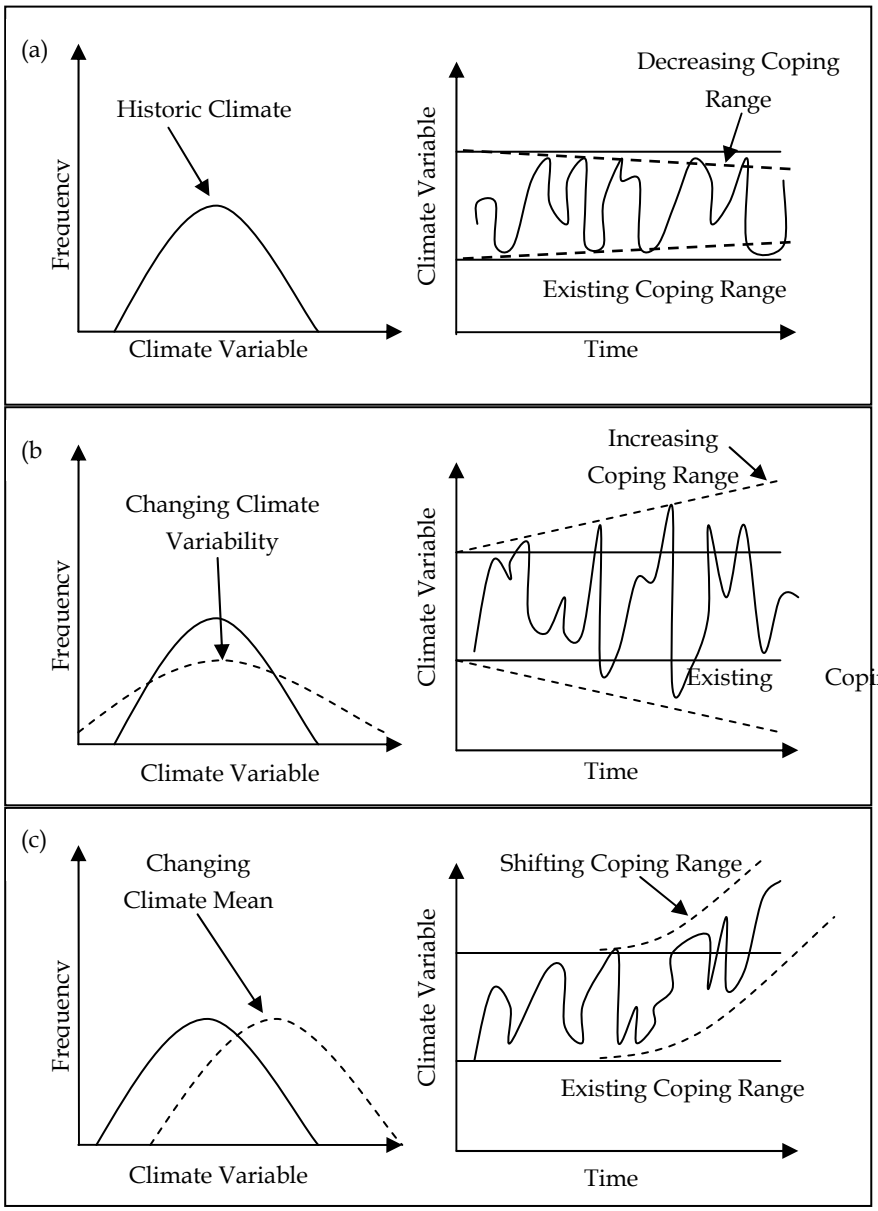
These examples illustrate a growing recognition in the scientific literature, namely the importance of viewing climate change within the context of multiple interacting stresses (e.g., IPCC 2001b; Turner et al. 2003; O'Brien et al. 2004; O'Brien and Leichenko 2000, 2003). Climate change adds to these pressures and will likely exacerbate many existing ecosystem and resource management concerns as well as health and economic risks (e.g., Smith and Galbraith 2003). Thus, programs that set out to enhance society's capacity to cope with climate variability and change must recognize that climate is just one of many challenges that communities, industry, resource managers and regional planners must manage. In fact, in many cases climate risks might rank low on the list of concerns or may not be a conscious element in management at all—as our empirical work with California's coastal and fire managers illustrated. Changes in population,

economic development, federal and state policies, technology and social values may be more important determinants of water supply or coastal management than climate-related stresses over the next few decades (see also IPCC 1996; Fredrick and Gleick 1999). Although even in the short term, climate is likely to aggravate conditions, the multi-stressor context highlights the need to integrate, or "mainstream," climate risk into ongoing decision and management processes.

Integrated resource management approaches provide a useful framework from which to build capacity to cope with current climate variability and to adapt to climate change within the context of multiple stresses. For example, integrated water resources management approaches have shown promise as a means for balancing multiple and changing demands water and other resources (IPCC 2001b). Such integrated water resource management plans seek "to ensure the coordinated development and management of water, land and related resources by maximizing economic and social welfare without compromising the sustainability of vital ecosystems" (Agenda 21, WSSD 1992). It is encouraging to note that California's Water Plan calls for the creation of incentives to support integrated water resource management (CA Draft Water Plan 2005). In the sections below, we explore additional opportunities to enhance coping and adaptive capacity in the state.

3.2. Building Coping Capacity to Deal with Current Climate Variability

California society and state economy have evolved over time to live with and take advantage of the state's diverse climatic zones and environmental conditions. The economies of the warm coastal regions of Southern Californian thrive on the beach-going residents and tourists. In the moderate climatic region of the Napa Valley, the climate sensitive wine industry has grown as the foundation of the local economy. And in the snow-rich Sierra Nevada, an important part of the economy has evolved around the climate-sensitive ski industry. Each of these regions has developed strategies to cope with climatic conditions that deviate from the mean, such as weather that is unusually hot, cold, wet or dry. For example, in extremely hot years, vineyards in the Napa Valley often harvest early so as not to avoid over-ripening (Cahill, personal communication). In unusually dry years, the ski resorts in the Sierra rely on snow-making equipment. However, each sector's ability to cope is often confined within a certain range of climatic conditions. This range is referred to as the "coping range" (Smit and Pilifosova 2003) (see Figure 3).



Source: Graphic representation based on Smit and Pilifosova 2003, Burton et al. 1993)

Figure 3: Changing Coping Ranges

To cope with its historical climate and climate variability, California has constructed reservoirs, built levees, developed information networks and hazard warning and emergency response systems. The water rights system in the state—established after settlement—may not have been designed with historical climate averages and variability in mind, but has functioned reasonably well within those climatic parameters. These structural, institutional, financial and legal mechanisms along with social capital and cultural norms all contribute to a society's "coping capacity" or "coping range" (e.g., Adger 2003; Brooks et al. 2005; Haddad 2005; Pelling and High 2005; Tompkins and Adger 2005).

Many of these customary coping strategies could be enhanced to widen the range of climate conditions that Californians can deal with without major harm. For example, heat/health watch and warning systems, cool-off spaces, and wider penetration of air conditioning in all homes and public buildings could help residents deal more effectively with heat waves (Kalkstein 2003). At the same time, increased use of air conditioning would increase energy demand during the hottest period of the year, increase the urban heat island effect, and—depending on the energy source—could actually increase greenhouse gas emissions.

However, a number of the coping strategies historically employed are also coming under increasing pressure from multiple non-climatic stresses that may make them gradually become less effective. For example, water storage capacity behind dams is declining as that space fills up with sediment; levees in the Sacramento-San Joaquin region will protect the land behind them less effectively from future coastal storms as average sea level rises. The result is that certain regions, sectors and populations are becoming more vulnerable to climate variability and change.

To reduce these growing vulnerabilities California will need to make adjustments to maintain or even strengthen current coping capacity. In the next two sections, we draw from the growing literature on coping with and adapting to climatic change to define a framework in which California can begin to identify and implement proactive strategies to build resilience to climate variability and change by strengthening coping capacity and preparing for change (see Textbox 2).

Textbox 2: Awareness – Analysis – Action: The AAA of Adaptation

To enhance society's preparedness for climate variability and change, decision-makers—be they in the private or the public sector—first need to become aware of the potential impacts and risks, and how these risks may affect them personally, collectively, or their specific management resort. This *awareness* needs to be coupled with a fuller understanding and the capacity to *analyze* such information. This can provide the necessary motivation and willingness to act. Moreover, decision-makers need to have the ability to use this understanding in decision-making, i.e., to translate their awareness and concern into concrete *actions*. Typically, the latter step involves removing institutional and other barriers that can prevent realization of well intended policies and plans.

A decision-maker with motivation and political will to act on climate variability and change may be able to translate such intent directly into a decision and action, or he or she may be in a position to design policy or guidance which then is implemented by others (this is frequently the case in the public sector where policies at the federal or state level must be implemented at the local level). At each level, awareness, analytic capacity, and ability to act must be met in order for implementation to actually occur.

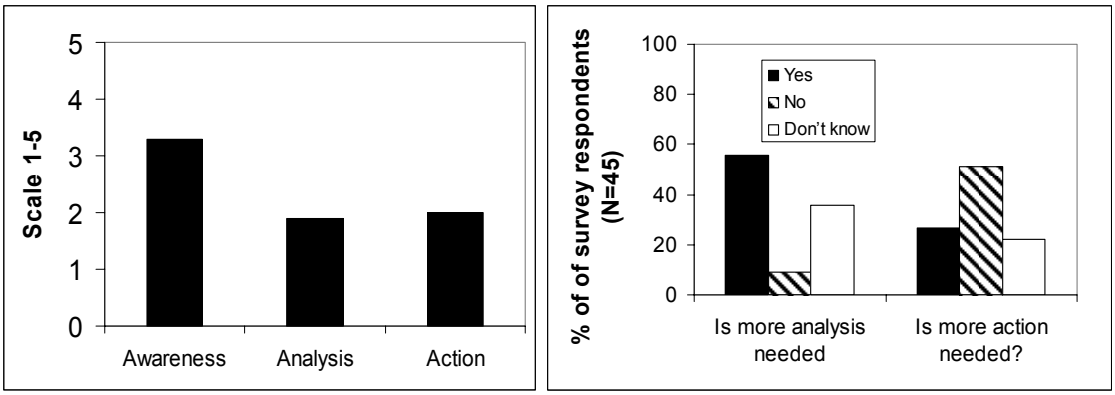
The United Kingdom Climate Impacts Group (UKCIP) has provided guidance to local authorities to prepare for climate change (UKIP 2003), which in many ways follows this

awareness-analysis-action approach. As outlined by Brooks et al. (2004) the UKCIP encourages local authorities to ask the following questions?

- Do you know how climate change could impact your area?
- Do your current policies, strategies and plans include provisions for the impacts of climate change?
- Can you identify and assess the risks from climate change to your services?
- Are developments with a lifetime of more than 20 years required to factor in climate change?
- Does your Emergency Planning Service take into account climate change?
- Are you addressing climate change in your local community strategy or community plan?
- Have you briefed your elected members on any key risks arising from climate variability and long-term climate change?

A similar assessment across California's private industry managers and public administrators would provide a helpful baseline from which to build institutional capacity.

For example an initial survey of wildfire managers in southern California indicates a moderate level of awareness of climate change as an issue, but little knowledge of the specific analysis on the implications climate change might have on the intensity and frequency of California wildfires (Figure 4 below). While many officials interviewed believed that more analysis should be done to understand the potential effects of climate change on wildfire, many also acknowledge that wildfire management is currently challenged with more pressing issues such as development pressures, financial constraints, and inter-agency coordination.



The results presented here are from a formal survey of 45 wildfire specialist from San Diego, San Bernardino, Riverside and Los Angeles County. Individuals were asked to rank the level of awareness in their organization of climate change, the level of relevant analysis that has been conducted regarding climate change impacts on wildfires, and the level of action taken to address climate change in their department. Individuals were also asked if they thought additional analysis the local implications of climate and wildfires was needed and if they thought additional actions were needed to prepare for wildfires in light of the changing climate.

Figure 4: Preliminary Assessment of Fire Managers' Awareness and Actions Related to Climate Change in Southern California

It is important to note that preparing for climate variability may or may not suffice to deal with climate change, depending on the nature of the future climate regime and associated environmental and social conditions. For example, a sustained program of brush clearance around development will help mitigate fire risk now and in the future, but the frequency and spatial extent of clearance operations may need to be adjusted based on vegetation changes, drought frequencies, and future development patterns. Thus, plans to deal with climate variability need to be assessed on a regular basis to make adjustments.

Key Finding #4: To enhance Californians' preparedness for climate variability and change, decision-makers in the private and public sectors require greater *awareness* of the risks they face, increased capacity to *analyze* such information and use it in decision-making, and the ability to remove any institutional, financial, political, and other barriers in the way of turning good intentions into *actions*.

3.3. Building Adaptive Capacity and Resilience in Light of Climate Change

Building adaptive capacity essentially means broadening the range of options for proactively or reactively reducing society's vulnerability and increasing resilience to climate change. While determined by a similar range of factors like coping capacity, this paper distinguishes the two here—maybe artificially—to emphasize the forward-looking future orientation.

Building resilience to climate change over the medium term will require more than reducing vulnerability and increasing capacity to cope with current climate variability. Human-induced changes in the climate system will likely be experienced in several ways: environmental and societal impacts can be stimulated by (1) gradual changes in average meteorological variables such as temperature and precipitation, (2) more frequent and/or more intense climatic extremes, and (3) climatic or other environmental and societal changes that amount to a "regime shift," i.e., changes that are so large or different in nature that society has no relevant historical experience or institutional mechanisms for handling them.[4] All three types of changes—if sufficiently large—can move society outside its experienced coping range (see Figure 3 above). For example, water resource management in California currently depends heavily on snow melt for its water supply. However, over the next few decades spring snow pack in the Sierra Nevada is expected to decline by 30%-40% (Hayhoe et al. 2004; see also Mote et al. 2005; Dettinger et al. 2004; Kiparski and Gleick 2003, 2004; Stewart et al. 2004; Miller et al. 2003; Kim et al. 2002). Adjusting to such substantial loss in surface water storage in a sustainable manner will require considerable forward-looking investment and planning.

Over the last decade, the global change research community has focused on understanding the causal structure of vulnerability and identifying strategies to enhance resilience of communities within the context of climate variability and change (Turner et al. 2003; Handmer et al. 1999; IPCC 2001b). Vulnerability, defined by the Working Group II of the IPCC (2001a) as the extent to which a natural or social system is susceptible to sustaining damage from climate change (see Textbox 1 above), is often characterized as a function of the system's *sensitivity* and *exposure* to changes in climate and its *capacity to adjust or absorb* the impacts created by a given change in climate. Thus, reducing vulnerability or enhancing resilience to climatic stress requires actions that either reduce a system's sensitivity and exposure or enhance its capacity to respond more quickly and recover more effectively from the effects of climate and interactive stressors.

There is a growing body of literature that offers insight into how specific regions or populations cope with climatic extremes, the conditions that promote or constrain the capacity to cope, and the relative effectiveness of specific coping strategies (e.g., Bohle et al. 1994; Kelly and Adger 2000; Adger et al. 2005; Smit et al. 2001). This literature builds on the theoretical frameworks of three distinct areas of study—food security, risk and hazard management, and ecological resilience—to identify general and specific determinants of adaptive or coping capacity (Brooks et al. 2005). Below, this paper briefly reviews a number of these strategies and mechanisms for enhancing adaptive capacity to climate change (drawing on Tompkins and Adger 2005; Brooks et al. 2005; Easterling et al. 2004; Folke et al. 2002; Klein and Tol 1997; Lambin 2005). It gives a

[4] One could imagine a case, for example, where climate changes are not particularly severe, but society's ability to cope has drastically diminished – for example, a substantial decline of the health care system, a collapse of the insurance industry, or a significant reduction in federal disaster aid. Such non-climatic changes, too, could produce a "regime shift" with a much diminished coping range when faced with the impacts of climate change.

general overview of the basic points of intervention and provide examples from climate-sensitive sectors in California.

3.3.1. Possible Points of Intervention

A number of mechanisms—enacted at different levels of government or by various actors in the private sector—can facilitate preparation for, and adaptation to, the unavoidable impacts from climate changes over the next few decades. Many of these mechanisms will not solely address climate risks, but serve multiple environmental, social, or economic goals. Possible points of intervention include, but are not limited to, the following:

- Enabling the Development and Application of Technologies

The availability of technologies is a critical component of enhanced response capacity in many climate-sensitive sectors (Tompkins and Adger 2005). One example is human health. California currently does not have any heat warning systems (Kalkstein 2003; Sheridan and Kalkstein 1998). A comprehensive set of technological and institutional advances could enhance the state's ability to deal with the projected increase in heat extremes (Hayhoe et al. 2004): greater forecasting capability of heat waves and extremes, spreading such information in a timely fashion to Californians in affected regions, especially the most vulnerable ones (such as the elderly, the young, and the infirm), including in languages other than English, alerting health care providers and mobilizing relevant response systems, and ensuring adequate supplies of clean electricity to power air conditioners.

- Enhancing Institutional Flexibility

The climate is changing and altering patterns of extreme events in yet-difficult-to-predict ways. This uncertainty is aggravated by the incomplete understanding of how social and ecological systems will respond to climate variability and change. As a result, planners and managers must increase their ability to deal with uncertainty and expect surprise (Bazerman and Watkins 2004; Brooks 1986; Gallopin 2002; Glantz et al. 1998; Janssen 2002; Kates 1985; Kates and Clark 1996). Greater institutional flexibility can enhance the capacity to manage uncertainty and respond to surprise (Gleick et al. 2002; Easterling et al. 2004; Berkes and Jolly 2001; Fredrick and Gleick 1999). For example, water markets may be an important proactive coping response as it may increase flexibility of water allocation to accommodate a wider range of climate conditions (Kiparski and Gleick 2004). However, while water markets provide opportunities, clear market guidelines must be provided to ensure equitable access, protect the environment, and ensure transparency (Gleick et al. 2002). Deliberate attempts to assess and learn from management "experiments" (adaptive management) will be facilitated by flexible institutional mechanisms and as such can also be critical for promoting social learning (Gunderson 1999).

- Providing Financial Resources

Financial resources to deal with the impacts of climate change are strained at the federal, state, and local levels. National and state-level debts, competing demands and priorities,

and unfunded mandates are just some of the reasons why many resist taking on yet another issue, especially one as big as climate change. It is precisely for that reason that pro-active climate management—shown to be more cost-effective than reactive measures—should be promoted more forcefully. Financial incentives from federal or State sources to assess community preparedness, for example, have proven important mechanisms to mobilizing action (e.g., Moser 2005). While sometimes challenging to realize, communities have found creative financing mechanisms (e.g., bonds) to invest in activities that have longer returns, but help protect or enhance their assets. For example, gradual land-use changes can lead to habitat fragmentation that can limit some species' ability to migrate and adapt to climate change (Parmesan and Galbraith 2004). However, land-use and management policies that focus on preserving migration corridors may reduce the risk of extinction of certain populations in fragmented landscapes (Ricketts 2001; Parmesan and Galbraith 2004; Fried et al. 2005) while preserving a highly attractive landscape mosaic that raises the value of adjoining real estate.

- Changing Cultural Norms

Cultural norms deeply affect the values, beliefs, expectations, and behaviors of individuals and whole societies. In present-day American society, for example, the right to private property—as codified in the Constitution—is a closely defended cultural value. Decades of certain social welfare programs have created an expectation of governmental support of the individual. Nearly a half-century of awareness-raising of the environmental impact of human activities has affected values, beliefs, and in some cases public policies and individual behaviors. These examples simply hint at the complex ways in which deeply anchored cultural norms enable or constrain possibilities for responding to climate change. Such norms change typically slowly, over the course of generations, and are most easily influenced at a young age through parental, informal and formal education. As the frequently cited example of teaching children about recycling suggests, even an intervention directed at the younger generation will influence the thinking and behavior of adults in indirect ways. Such pathways and opportunities may be useful avenues for efforts to facilitate individual adaptations.

- Building Social Capital

Social capital—loosely defined as informal networks of trustful relationships within an organization, community or society – is viewed increasingly as a critical determinant of adaptive capacity, even if it is difficult to measure (e.g., Pelling and High 2005; Adger 2003). Communities with greater social capital tend, for example, to share more quickly and readily critical information that might enable them to respond to climate signals, identify relevant resources, mobilize people and so on. As coastal managers in California suggested, such information exchange (e.g., across state agencies) has much improved over the past few years, but still heavily depends on individuals. Thus, any efforts that could help develop information and tools that would facilitate information exchange, support adaptive management, foster smooth decision processes, and reward forward-looking planning capabilities would build social capital in the state.

- Improving Science–Practice Interactions

Adequately and effectively preparing for climate change requires the best available scientific and other information, because and despite of the fact that many adaptation decisions will have to be made in the face of persistent uncertainty. More frequent interactions between the science and the policy-making and management communities are required. Frequently still, such science–practice linkages are ad hoc and of inconsistent quality (Vogel et al., forthcoming). Thus, while California is among those states in the union with exceptional scientific capacity, the State may consider providing incentives and more effective mechanisms to establish better science–practice interactions to support and enhance the exchange between providers and users of information.

Improvement in the science–practice interaction clearly should be approached from both sides. Currently, many resource managers do not use climatic information for their day-to-day responsibilities. Others do use information about current weather and climate, but are not required to look toward the future and consider the possibility of a different climate in decisions that will have long-term impacts. Their professional responsibilities may not formally require it. For example, coastal managers in California must consider historical sea-level rise when calculating setback distances from the oceanfront, but are not presently required to calculate such setbacks under the assumption of a faster rate of sea-level rise (see also Textbox 3).

Textbox 3: Information Needs of California Coastal Managers[5]

The 1,100 miles of coastline of California are at once one of the state's major attractors for development, economic activity, tourism, and recreation, and also critically at risk from the combined impacts of climate change. Sea-level rise, coastal storms, changing rainfall and runoff patterns into the coastal ocean, increases in coastal water temperatures, species shifts, and higher temperatures will combine to create unique challenges for coastal managers. Responsibilities for coastal management are spread over multiple institutions, including federal and state agencies, state commissions, regional councils, and local government. The latter is principally responsible for implementing laws and development plans. Policy- and decision-makers at federal, state, regional, and local levels are concerned with:

- Development, planning and supporting diverse economic activity in the coastal zone
- Siting and appropriate construction of homes, businesses and related infrastructure
- Protection of coastal development and residents from natural hazards such as floods, erosion, cliff failures, earthquakes and tsunamis, fires etc., including prediction, preparedness, warning, disaster response, and recovery-related responsibilities
- Provision of water, energy, and other infrastructure to coastal dwellers
- Protection of water resources and quality in coastal inland waters and in the coastal ocean
- Provision of recreation areas (e.g., beaches, state parks)
- Protection of habitat and species (e.g., dunes, wetlands and associated plants and animals, several of them threatened or endangered)

This diversity of responsibilities and underlying goals point to the diversity of needs, the range of opportunities—and the potential for conflict—involved in enhancing California's coping/adaptive capacity in the coastal zone. Moreover, the cross-scale collaboration and integration of management efforts can be challenging. Currently coastal managers are not required to consider future climate in their planning or management decisions. They typically don't have the time, staff or financial resources to examine potential impacts of climate change on their management responsibilities. Some are highly knowledgeable about climate change while others are unaware or only marginally knowledgeable of the potential for harm that climate change could bring to coastal areas of California. A majority does not use weather-, climate-, or sea level-related information in their decision-making today. Thus, the biggest hurdle to overcome is for coastal managers to consider climate change in their management activities at all. At the same time, it should not be assumed that awareness or the availability of information alone will solve the management challenges faced in coastal California (similar findings have been made in other regions and sectors, see e.g.,

[5] For this preliminary study, key federal, state, and regional governmental decision-makers involved in California coastal management were interviewed to qualitatively explore the state's coping and adaptive capacity. A particular focus was managers' information needs should they begin taking climate change and projections of a higher sea level into account. The study is ongoing and will be complemented with a survey of local-level decision-makers. A full report of this case study will be prepared separately.

Changnon et al. 1995; Golnaraghi 1997; Pulwarty & Redmond 1996; Callahan et al. 1999; Ray 2003; Cash 2003; Rayner et al. 2002; Jacobs 2002). The capacity to assess and analyze available information and use it in decision-making and the ability to overcome any institutional, organizational, financial, or political barriers to action are often as or even more important.

To the extent information and awareness are limiting factors science can play a critical role in filling such information gaps and raising managers' awareness and understanding of climate change risks. More specifically, this study revealed the following information-related needs:

Specific management-related information needs

- Translation of projected sea-level rise and changes in coastal ocean and wave climate into shoreline retreat, beach erosion, and bluff retreat rates (this would help determine setback distances from the shoreline or edge of the bluff); expressed for several planning- or project-relevant timeframes (20–25, 50, 75 years)
- Information about potential changes in future coastal storm frequency
- More reliable forecasting of El Niño events, and any changes in the frequency or severity of such events, as they strongly influence the variability in storm frequency, and how these changes would affect the shoreline retreat rates
- Remapping of flood zones under different sea-level rise projections (this would affect siting and construction standard decisions in floodplains[6] and emergency and evacuation plans)
- Information about potential changes in run-off and near-shore coastal and estuarine water temperatures and exploration of the implications of such changes for water quality, water availability, and aquatic ecology

Information management and accessibility needs

- Exchange of information among all coastal states and coastal communities about their responses to climate change-related impacts and risks
- Better collaboration and exchange of relevant information among all involved agencies (federal, state, local – as needed for different management resorts)
- Integration of existing (and additionally developed) information into common formats, e.g., geographic information systems
- Accessibility of integrated databases at various levels of spatial aggregation/resolution (e.g., state, local, watershed/littoral cell levels) and for different temporal resolutions (e.g., calculation of erosion over a variety of specified time increments)
- Adequate funding of ongoing monitoring of critical, management-relevant variables

[6] Improvement of California floodplain maps is already underway under the auspices of the American Technology Council and could be enhanced through consideration of climate change-related changes.

- Priority should be given to making information accessible at the level where managers make ultimate decisions.

Information needs about uncertainty

- Provision of uncertainty ranges around projections to indicate scientific confidence
- Distinction between more and less likely impacts (e.g., "at-least sea level rise" vs. "maybe-as-much-as sea-level rise")
- Provision of scientific basis for uncertainty buffers (e.g., additional setbacks, extra capacity for storm water runoff)
- Interviewees suggested, however, that uncertainty per se is not the critical challenge in determining possible responses. Needed instead is a broader debate about the acceptability of individual vs. public risks and how the responsibility in case of impact should be shared.

Trusted sources of information

Interviewees differed in their preferences regarding who should produce such information. Interviewees expressed underlying concerns over which institution would be most trusted, most scientifically credible, and least "political" from the perspective of the information user. Suggested information providers included:

- Federal Emergency Management Agency (FEMA)
- National Oceanic and Atmospheric Administration (NOAA)
- United States Geological Survey (USGS)
- Scripps Institution of Oceanography (SIO)
- California's Ocean Protection Council.

Ideally, the needed information would not just be "made available" – even in a timely fashion and accessible language and formats, but be conveyed in training sessions to coastal managers who currently are not yet concerned with climate change. These trainings would help make abstract climate change and generic impacts more "imaginable" through local or regional examples and case studies, and examine the technical, institutional, economic and social sides of potential management options.

3.3.2. Mainstreaming Adaptation into Everyday Management

"Mainstreaming" adaptation means using or creating mechanisms that allow decision-makers to integrate future climate risks into all relevant ongoing policy interventions, planning, and management. Increasing adaptive capacity involves pro-active steps that consider anticipated future risks in day-to-day decision-making and management today, especially where these decisions have long-lived impacts. Such actions increase the likelihood that infrastructure and other long-term investments remain robust even under changed climatic and environmental conditions. In fact, they may well stimulate innovation and economic growth (e.g., Kabat et al. 2005). For example, coastal land-use planning and decisions over where to site development today requires consideration of how higher sea levels, increased erosion, and potentially increased flooding may affect

buildings and infrastructure over the next 70 years. This timeframe would cover the typical life span of new construction. Failing to do consider these long-term implications may create difficult-to-manage flooding and erosion hazards, eliminate the possibility for coastal wetlands to migrate inland, and place enormous investments at costly risk.

A related example is hazard management and emergency preparedness. Such plans require periodic update for other reasons than climate change (e.g., population growth, land use change or infrastructure maintenance). Plan reviews offer the opportunity to reassess whether relevant environmental hazard management and response systems in the state are able to cope with the likely increase in frequency and intensity of extreme climate-related events. Hazard management ranges from preparedness, monitoring, and warning prior to a hazardous event, to disaster response during an extreme event, to risk-sharing mechanisms such as insurance, to the recovery and rebuilding after the disaster. Such hazard management plans need to be specific to the hazard, to the location of where such events might be expected and must consider the future climate projections. For example, preparing adequately for extreme heat events and their potential human health impacts is different under varying climatic projections and over different regions such as large urban areas in northern or southern California versus rural areas in the Central Valley. Relying on historical experience of hazardous events—as is currently common practice—is unlikely to suffice as climate change alters typical frequencies and intensities of extreme events. Yet using regularly scheduled or episodically arising opportunities to update and upgrade policies and plans appears to be the "path of least resistance" to enhance California's readiness for climate change. The question is: will it be done?

3.4. Constraints on Coping and Adaptive Capacity

Proactive measures to building resilience to climate-related stresses are likely to be more effective if they are designed from a fuller understanding of current coping capacities and what factors limit them. Following our framework of Awareness-Analysis-Action introduced above (see Textbox 2), we suggest that it can provide a systematic way to examine the constraints that could limit the realization of California's significant coping and adaptive capacity.

3.4.1. Lack of Awareness

As the preliminary findings from the studies of California fire and coastal managers suggest (see Textboxes 2 and 3 above), many of those who would be in charge of implementing adaptation policies and decisions, especially at the local level, are currently unaware or unconcerned with climate change, or do not feel that it is their responsibility to address potential impacts in their spheres of responsibility. We found both the understanding and the motivation to address climate change low in many cases. Clearly, this finding has to be viewed in the context of countless pressing ongoing and near-term concerns, which for good reason absorb most if not all of the managers' currently available time, attention, and resources. However, enhancing ability to manage climate variability today can assist in building resilience for further climate change tomorrow. Thus by enhancing managers' awareness of future threats, and building their understanding of how preparedness for future climate change can be built into today's management responsibilities, the ability to cope with current and future climate

variability and change can be enhanced. However, significant educational effort is needed along with incentives, staff and financial resources to motivate resource managers to engage the topic in their day-to-day lives. Because of the rapidly changing science of climate change impacts, the long-term nature of the problem, combined with competing and distracting demands on managers' attention, the difficulty to maintain motivation to act on any long-term problem, and staff turn-over (especially the expected wave of retirements in the near future from many State agencies (McIntosh 2005), institutional memory is likely to be limited and will require regular refreshing for years to come.

3.4.2. Insufficient Ability to Analyze Climate-Relevant Information and Use it in Decision-Making

The ability to understand climate change (impacts) information and link it effectively to management responsibilities and decision processes is highly uneven in the sectors we have begun to examine. In part this linkage is hindered by the fact that scientific output does not easily or directly match the information needs that could inform management decisions (see the need for improved science–practice interactions discussed above). In part, this is because decision-making varies considerably in the sophistication of tools and information used at present. For example, while sea-level rise projections are valuable as a general indicator to raise awareness of future coastal risks in a general sense, permitting officers who determine setback distances to site new buildings need to know how these projections translate—together with possible changes in storm activity —into future coastal erosion rates. Emergency managers need to know how such future changes affect evacuation routes and would rather look at maps indicating changes in 100- and 500-year flooding risks than at a graphic of average sea-level projections.

As suggested in Textbox 3, many managers would appreciate not just more information, however potentially useful. Several mentioned trainings in how to use such information as an important capacity building strategy for California.

Enhancing managers' ability to analyze and use climate-relevant information in their decision-making, again, requires long-term commitment as it involves training and institutional capacity building, including building sustained or even institutionally formalized science–decision-maker interactions or positioning well trained experts in state and local agencies.

3.4.3. Constraints on Action

The constraints on action are basically the opposites of the same factors described above that—in theory—enhance coping and adaptive capacity: lack of financial resources, technical or technological constraints, institutional constraints and inflexibilities, cultural norms that predispose individuals, communities or entire societies to short-sighted and maladaptive responses, constraints arising from imbalances in political power or other positioning and delaying tactics, and importantly lack of social acceptability of different adaptation options. While the first few factors frequently constrain the motivation to act, the latter few appear to be the ultimate lynchpins on implementation. Even cursory insights from the history of progress in hazard management (most recently illustrated in the devastating impacts from Hurricane Katrina in the Gulf Coast region) (e.g.,

Weichselgartner and Obersteiner 2002; Glantz 2005), or from a review of the implementation of so-called lessons learned after major El Niño events along the U.S. west coast and around the globe (Glantz 2001), strongly suggest that society fails again and again at taking these hard-won lessons to heart and acting on them subsequently.

The empirical research for this report suggests that State policy-makers should be highly skeptical and carefully aware of the practical limitations that decision-makers at all levels face in preparing for the impacts of climate change. Coastal zone managers interviewed for this study, for example, repeatedly mentioned harsh and persistent, and frequently litigious struggles between interest groups over questions of shoreline protection and development—struggles that absorb crucial financial and staff resources, create political stalemates and produce a climate of conflict in which long-term visions would be very difficult to discuss. Moreover, even if coastal communities could resolve legal, technological and related aesthetic and social acceptability challenges, the question would still remain who—at the federal, State, and local level—could or should pay for shoreline protection and its long-term maintenance.

Likewise, water managers in California are still caught in an arcane system of water rights allocations, and face challenging trade-offs between water supply and flood management—in each case affecting wide areas, critical infrastructure, and important economic sectors of the state.

Large-scale economic and demographic forces drive sprawl and development patterns at the urban-wildland interface, thus creating challenges and legacies for fire managers which are beyond their local ability to control (see also Collins 2005). They literally, and other resource managers figuratively, repeatedly speak of being able only to focus on "putting the next fire out" rather than taking the long-term view.

These examples merely begin to shed light in purely qualitative terms on the real-life constraints that make implementation of adaptation options in California not only difficult, but quite likely slow, thereby possibly missing cost-effective windows of opportunities when they open, and conflict-ridden. Strong leadership and dedicated commitment for the long haul will be required to overcome or at least lower these hurdles. Importantly, policy-makers at the State and local levels must be aware that California's capacity to cope and adapt is uneven at present, as is the ability to realize that existing potential.

Key Finding #5: Many opportunities for enhancing California's adaptive capacity and resilience in the face of change exist. In fact, California's adaptive capacity—the *ability* to adapt—is significant. However, implementing that capacity into real adaptive actions on the ground is actually quite difficult and requires special attention and long-term commitment at all levels of government, across climate-sensitive industries, and throughout society.

3.5. The Differential Ability to Cope and Adapt: Environmental Justice and Climate Change

It is broadly understood that the effects of climate change will not be equally distributed across sectors, populations and regions (e.g., Tol et al. 2004; IPCC 2001b; Baer et al. 2000; Munasinghe 2000). For example, vulnerability to health effects associated with climate change varies depending on a range of socio-economic factors including wealth and age (Epstein 1994; Kalkstein 1998; Ebi et al. 2005). Agriculture is another example where large distributional effects are expected (Parry et al. 1999; Easterling 1997). While national assessments of the projected impacts on agriculture and forestry as a whole show little or no change, regional analyses indicate that there will be winners and looser (e.g., O'Brien and Leichenko 2003; CBCF 2004). The most vulnerable regions and communities are those that are most exposed and sensitive to the effects of climate variability and change and have the least ability to cope or adapt to its impacts (e.g., Tol et al. 2004; Smit et al. 2001).

Of particular concern are the potential social equity implications of climate change (e.g., Tol et al. 2004; Brown 2003; Paavola and Adger 2002; Byrne et al. 1998). Many studies have demonstrated that the poor and people of color in the United States and across the globe already face greater health and environmental than the society at large (e.g., CBCF 2004; Sagar and Banuri 1999; Williams 1999). For example, Kalkstein and Greene (1997) found that residents within inner cities in the United States, which are disproportionately populated by low-income inhabitants, face a greater risk of heat-related mortality than non-inner city residents. Similarly, McGeehin and Mirabelli (2001) found that the probability of heat-related mortality was twice as high for African Americans as for Whites in U.S. urban areas. The increased susceptibility to heat-stress in certain populations may be partly attributed to the well-documented differential access to health care resources across racial and socio-economic classes (Collins et al. 2003; Collins et al. 2002; Doty and Ives 2002), but also to greater exposure (e.g., farm workers unable to escape the heat). For example, African Americans, Hispanics, and Asians are among those populations with the lowest health insurance coverage in the United States (Bulatao and Anderson 2004).

Without appropriate actions, climate change will likely aggravate existing equity issues within California and the rest of the United States (CBCF 2004). More research needs to focus on identifying the most vulnerable populations, sectors and regions to climate variability and change. In particular analysis should focus on the distributional affects across socio-economic and racial groups. In addition, specific attention must be paid to addressing the needs of the already-disadvantaged populations and levering their strengths and capacities wherever possible.

<u>Key Finding #6</u>: The ability to cope and adapt is differentiated across population, economic sectors, and regions within the state. The State has an opportunity to ensure and enhance "environmental justice" while fostering California's adaptive capacity to climate change and other interactive stressors.

4.0 Conclusions and Recommendations

Developing and implementing a plan to effectively manage climate change will require a broader discussion on the needed societal response that should involve all levels of government, the private sector, and civic society. Such a discussion should—at a minimum—address the following questions:

- What level of climate change (or risk of change) is society willing to accept (thus also raising questions about the extent of greenhouse gas mitigation)?
- What goals should adaptation achieve, e.g., preserving the status quo, actively managing change toward new conditions, deeper societal changes required for sustainability?
- What is an acceptable level of individual vs. public risk and how should the responsibility in case of impact be shared?
- What are the social justice, environmental, economic, and other trade-offs associated with allocation of scarce resources as more systems come under growing pressure from climate and other stresses?

To fulfill the mandate contained in Governor Schwarzenegger's Executive Order S-3-05 to "report on mitigation and adaptation plans to combat [climate change] impacts," it is necessary to begin with an understanding of the fundamental processes that enhance or constrain the State's ability to cope with and adapt to climate change. Many of these factors will be determined by drivers emanating from outside of California – such as global market forces or national framework policies. At the same time, the State has a tremendous and critical influence on regional and local capacity to deal with the unavoidable impacts and to assess opportunities and constraints in preparing for potential future impacts of climate change. As an economically vibrant, technologically innovative, and frequently courageous political pioneer state, California may have a greater capacity than some to face the challenges from climate change.

At the same time, California is also highly exposed and many of its ecosystems and economic sectors are critically sensitive to higher temperatures and changing precipitation patterns, while the obstacles in the way of enhancing its resilience are nothing short of formidable. A concerted focus on further researching, quantifying, and addressing these constraints is clearly needed. More specifically, this study's authors propose actions at three levels, each discussed in some more detail in the sections below.

4.1. Government and Policy Actions

Government at both the State and Federal level can play a crucial role in stimulating and facilitating lower levels of government (regional and local institutions, which often are the implementing arms of government) and the private sector to begin exploring the growing risks from climate change, options for addressing them, and providing incentives to implement them. Examples include:

- Fund state-, region- or location-specific assessments of adaptive capacity
- Establish mechanisms that increase lower level governmental accountability vis-à-vis state-set climate-related and other environmental goals (e.g., no net loss of particular habitats, implementation of planning goals or building standards)
- Initiate (and provide adequate funding and staff to arrange) public forums to discuss climate change risks and response options; forums could be agency-specific or location-specific, for private sector, public officials, or the general public
- Provide financial incentives, initiating institutional changes (including a review and revision of agency mandates and job descriptions), or even pursuing legislative mechanisms to mandate climate-conscious planning and management
- Lead by example in all efforts under State jurisdiction that involve natural resource management and planning, and implement such efforts under an "adaptive management" paradigm in order to learn from those management strategies and improve and adjust them over time.

4.2. Future Research Directions

State and federal agencies can also enhance the adaptive capacity by building the necessary knowledge base for adaptation. Emerging from the discussions in this report are the following research priorities on adaptation for the State of California:

- Encourage research that uses a vulnerability approach to assess climate change and coping strategies
- Encourage research that seeks to expand the knowledge of resource managers regarding climate and weather risks and how risks affect coping/adaptation options
- Encourage research that identifies thresholds and sensitivities agricultural and natural landscapes or other climate-sensitive sectors; in particular, pursue management-relevant questions into species migration, landscape connectivity, and "rolling" easements for protected areas that would afford species habitat protection as environmental conditions change
- Encourage research into the socio-economically and racially differentiated vulnerabilities to, and capacities to deal with, the impacts of climate change
- Encourage research into the feasibility of adaptation options against the backdrop of climatic, economic, technological, institutional, social, legal, ecological or other constraints
- Encourage further sector-specific empirical research into what specific information needs resource managers have; how they process information about climatic risks, identify and assess coping strategies, and choose whether, when, and how to employ them. To date much of the empirical work has been based on case studies in a developing world setting which is not always directly transferable to the developed world context.

- Respond to these identified information needs of different decision-makers by providing information that is directly relevant and easily accessible to different stakeholders' decisions

4.3. A Role for Civil Society in Fostering Public Dialogue on Adaptation

Finally, because the American public "debate" to date over climate change has largely focused on the need for mitigation, i.e., reducing the emissions that cause human-induced climate change and a wider discussion of the parallel need for adaptation has not yet taken place, civic society has a significant role to play in preparing for change.

Recognizing the state of the science about climate change, the debate over the two sides of societal response to climate change needs to be reframed as one of complementary necessities. Without such an informed public conversation about coping and adaptation, pro-active steps and strategies will not be explored, much less implemented. This would leave society to cope in inefficient and probably more costly ways as further impacts manifest in the future. Uncertainties about future climate thus imply no delay in this self-reflection and examination at all, but instead suggest a profound governmental and civic responsibility for initiating public dialogue and working toward the well-being of all members of society.

Specific steps civic actors can take may include:

- Scientists can play a bigger role in educating the interested public as well as local, regional, and State decision-makers about the need for adaptation, thus stimulating public discussion of the potential options and constraints on coping and adaptation
- Environmental advocacy groups may begin examining how climate change may impact their interests and goals and help identify win-win solutions
- Private sector businesses need to identify their exposure and risks in light of climate change, and begin identifying measures that help reduce their vulnerabilities over the short-, medium- and longer-term

Preparing for and adapting to the impacts of climate change will take committed, ongoing and collaborative effort from government, the private sector, the research community, and civil society. While the challenges are large, California has a history of leading the nation in terms of policy and forward-looking management approaches. The State has an opportunity once again to advance the debate and lead by example.

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